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MICRO SAINT MODELING OF PHYSIOGICAL RESPONSES AND HUMAN PERFORMANCE IN THE HEAT

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13. ABSTRACT *(Maximum 200 words)*

This report documents a Micro SAINT implementation of a heat-stress model developed by the U.S. Army Research Institute of Environmental Medicine. The model incorporates equations that relate deep-body temperature, heart rate, and sweat loss for clothed soldiers performing physical work in various environments. The Micro SAINT program might be used to help reduce casualties associated with extremes of environmental heat, to calculate appropriate work-rest cycles, and to estimate the drinking-water requirements associated with various levels of sweat loss.

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CONTENTS

ABSTRACT

We developed a Micro SAINT computational program that executes a series of predictive equations, developed by the U.S. Army Research Institute of Environmental Medicine, for deep-body temperature, heart rate, and sweat loss responses of clothed soldiers performing physical work at various environmental extremes. The user can employ the program by inserting input parameters in the scenario section of the MicroSAINT program.

The developed program could be used to help avoid casualties associated with environmental heat extremes, to predict appropriate work-rest cycles, or to predict water requirements due to sweat loss.

Acknowledgments

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1. INTRODUCTION

For the last two decades, the U.S. Army Research Institute of Environmental Medicine (USARIEM) has been establishing a data base and developing a series of predictive equations for deep-body temperature, heart rate, and sweat-loss responses of clothed soldiers performing physical work at various environmental extremes. Predictive equations for rectal temperature, heart rate, and sweat loss as functions of physical work intensity, environmental conditions, and particular clothing ensembles have been published in the open literature (1-11).

In this report, we describe a Micro SAINT (12) computer model based on the USARIEM equations for deep-body temperature, heart rate, and sweat loss. The Micro SAINT program is written with a user friendly approach. The user may supply the input parameters in the scenario section of the program and obtain the results as output stored in Micro SAINT snapshot files. As such, the user may view the main program as a "black box" because input and output information are stored separately in the scenario and snapshot sections of the Micro SAINT program.

The following sections constitute a detailed summary of the USARIEM heat-stress model, the Micro SAINT model, and an illustration of how to use the Micro SAINT program. The Micro SAINT program is listed in the appendix and can be obtained from the authors in return for a 5 1/4 inch, double-sided, double-density disc and a self-addressed disc-mailing envelope.

2. MATHEMATICAL EQUATIONS

EQUILIBRIUM RECTAL TEMPERATURE AND HEART RATE PREDICTIONS

The general formula for predicting the final equilibrium rectal temperature (T_{ref}) suggested by Givoni and Goldman (1) ... Pandolf et al; (6) is:

$$T_{ref}(^{\circ}C) = 36.75 + 0.004(M - W_{ex}) + 0.0011\ H_{r+c} + 0.8\ \mathrm{Exp}[0.0047(E_{req} - E_{max})] \tag{1}$$

Equation 1 is comprised of three components: metabolic, dry heat exchange, and evaporative heat exchange. The metabolic component is

$$[37.75 + 0.004(M-W_{ex})]$$

in which

$$M = 1.5\ W + 2.0\ (W+L)(L/W)^2 + \eta(W+L)[1.5\ V_w^2 + 0.35G_wV] \tag{2}$$

as published by Pandoff et al. (5), and

$$W_{ex} = 0.098G(W+L)V_w \tag{3}$$

as published by Givoni and Goldman (1), where

M = metabolic rate (watts)

W_{ex} = external work (watts)

W = nude body weight (kg)

L = clothing and equipment weight (kg)

η = terrain factor (defined in Table 1)

V_w = walking velocity (m/s) and

G = grade; (%)

The dry heat exchange component is

$$[0.001\ H_{r+c}]$$

where

$$H_{r+c} = 6.45\ A_d(T_{db} - \overline{T}_{sk})/I_t$$

as given by Givoni and Goldman (1)

A_d = body surface area (m^2)

T_{db} = dry bulb temperature (°C)

T_{sk} = average skin temperature (°C)

I_t = total insulation including air layer (I_a) and intrinsic clothing (I_{cl})

The evaporative heat exhange component is

$$0.8 \exp [0.0047\ (E_{req} - E_{max})]$$

as given by Givoni and Goldman [1] where

$$E_{req} = (M - W_{ex}) + H_{r+c}$$

and

$$E_{max} = 14.21\ i_m/I_t\ A_{deff}\ (P_{sk} - d_a P_a)$$

where

i_m = permeability index (N.D.)

A_{deff} = effective surface area for evaporation (m^2)

P_{sk} = water vapor pressure at the skin (mm Hg)

ϕ_a = relative humidity (%) and

P_a = saturated water vapor pressure of air at T_{db} (mm Hg)

The terrain factor η is determined from the following table according to the type of terrain:

TABLE 1. Terrain Types and Terrain Factors.

Black top	Dirt	Light brush	Hard, packed snow	Heavy brush	Swampy bay	Loose sand	Soft snow
Terrain number							
1	2	3	4	5	6	7	8
Terrain factor η							
1.0	1.1	1.2	1.3	1.5	1.8	2.1	1.3 + 0.08

The final equilibrium heart rate HR_f (beats/min) in a given cycle is given by (2).

$$HR_f = \begin{cases} 65 & I_{hr} < 25 \\ 65 + 0.35\,(I_{hr} - 25) & 25 \leq I_{hr} \leq 225 \\ 135 + 45\,[1 - \mathrm{Exp}[-0.01(I_{hr} - 225)]] & I_{hr} > 225 \end{cases} \qquad (4)$$

where

$$I_{hr} = 100(t_{rec.eqlb} - 36.76) + 0.4\ W_{ex} \qquad (5)$$

SWEAT LOSS PREDICTION

The general equation for predicting sweat loss response (Δm_{sw}) as a function of exercise, environment, and clothing interaction as proposed by Shapiro et al. (11) is

$$\Delta m_{sw}(\mathrm{gm^{-2}h^{-1}}) = 27.9\ E_{req}\ E_{max}{}^{-0.455} \qquad (6)$$

where

Δm_{sw} = change in body weight from sweat loss.

This formula can be employed over a wide range of E_{req}(50 - 360, W m^{-2}) and E_{max}(20 - 525, W m^{-2}), and it is most applicable for predicting water requirements.

WORK-REST CYCLE PREDICTIONS

The physical work-rest cycle and the time patterns of rectal temperature and heart rate are given for three different conditions:

(a) the time pattern for resting subjects under various heat stress conditions referred to as "resting" T_{ret} (resting rectal temperature at any time t) and "resting" heart rate $HR_{t(r)}$;

(b) the elevation pattern for rectal temperature during physical work at the given climatic conditions referred to as "working" T_{ret} (rectal temperature at any time t after beginning physical work) and "working" heart rate $HR_{t(w)}$; and

(c) the recovery rectal temperature after cessation of physical work referred to as "recovery" T_{ret} (rectal temperature at any time t after completion of physical work) and "recovery" heart rate $HR_{t(rec)}$.

The following governing equations have been presented and discussed in detail elsewhere (1).

Resting Cycle

Rectal Temperature at Rest (T_{ret}).

$$T_{ret} = T_{reo} + 0.1 \ \Delta \ T_{re} \exp[0.4^{t-0.5}] \tag{7}$$

where

T_{ret} = rectal temperature at any time t

T_{reo} = initial rectal temperature (°C)

ΔT_{re} = difference between the new final equilibrium rectal temperature T_{ref} in the new environment and T_{reo}

t = time (h)

The exponential power factor, t − 0.5, allows a 30-min period for the initial lag in resting rectal temperature change when the elevation reaches about 0.1 of the total change.

Heart Rate at Rest ($HR_{t(r)}$).

$$HR_{t(r)} = 65 + (HR_f - 65)(1 - e^{-3t}) \tag{8}$$

where

HR_f = equilibrium heart rate

t = time in hours (h)

The heart rate at rest in comfortable conditions is assumed to be 65 beats/minute.

Working Cycle

Rectal Temperature at Work.

$$T_{ret} = \begin{cases} T_{reo} + 0.1 \ \Delta T_{re} \operatorname{Exp}[0.4^{t-0.5}], \ t \leq 0 & (9) \\ T_{reo} + \ \Delta T_{re} [1 - \operatorname{Exp}[-2 \bullet \operatorname{Exp}(-0.17 \ \Delta T_{re} \hat{t})]] & (10) \end{cases}$$

where

$$\hat{t} = t - \frac{58}{M}$$

$$\Delta T_{re} = T_{re} - T_{reo}$$

Heart Rate at Work.

$$HR_{t(w)} = 65 + (HR_f - 65)[1 - 0.8 \text{ Exp } [-(6 - 0.03 (HR_f - 65)t] \qquad (11)$$

Recovery Cycle

Recovery Rectal Temperature T_{ret}.

$$T_{rst} = \begin{cases} T_{recwork} + 0.5 (T_{recov} - T_{recwork}), & t < t_{drec} \\ T_{rew} - (T_{rew} - T_{rer})[1 - \text{Exp}\{-\alpha(t - t_{drec})\}], & t > t_{drec}, \end{cases} \qquad (12)$$

where

$T_{recov} = T_{reo} + (T_{ref} - T_{reo})[1 - \text{Exp}\{-2.0 \text{ Exp}(-0.17(T_{ref} - T_{reo})(t - \frac{58}{M}))\}]$

T_{rew} = rectal temperature at the beginning of decrease (°C); T_{rew} is not necessarily equal to T_{re} at the end of work

T_{rer} = equilibirium resting rectal temperature (°C)

α = time constant of recovery

$= 1.5 [1 - \text{Exp}\{-1.5 CP_{eff}\}]$

$t_{drec} = 0.25 \text{ Exp}\{-0.5 CP_{eff}\}$

$CP_{eff} = 0.27(\frac{im}{clo})[P_{sk} - \phi P_a] + (\frac{0.174}{clo})(36 - T_a) - 1.57$

Heart Rate During Recovery.

$$HR_{t(rec)} = HR_w - (HR_w - HR_r)[1 - \text{Exp}(-kbt)] \qquad (13)$$

where

HR_w = heart rate at the end of the work period

HR_r = equilibrium heart rate for resting at the given climatic and clothing conditions

Model: heat   Network: 0 heat

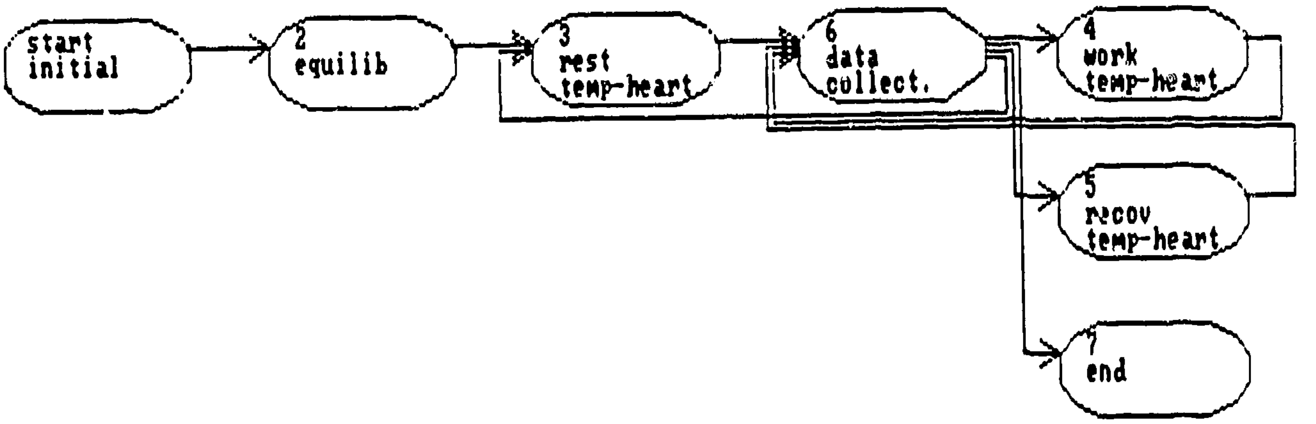


Figure 1. A Micro SAINT Network diagram printout.

$k = 2 - 0.01(HR_w - HR_r),$

$b = 2.0 + 12[1 - Expp(- 0.3CP_{eff})].$

CLIMATIC AND CLOTHING CONDITIONS

The climatic/clothing conditions parameters, im and clo, are to be computed using

$$clo = c_1 V_{eff}^{-c_2}$$

and

$$\frac{im}{clo} = c_3 V_{eff}^{-c_4}$$

where

$$V_{eff} = V_{air} + 0.004(M - 105) \text{ m/s}$$

and c_1, c_2, c_3 and c_4 are taken from the following tables for different type of clothing.

TABLE 2. Constant Parameters for Different Type of Clothing.

Clothing type	c_1	c_2	c_3	c_4	closcond
Shorts	0.57	0.3	1.2	0.3	1
Shorts and short-sleeved shirts	0.74	0.28	0.94	0.28	2
STD (standard fatigues)	0.99	0.25	0.75	0.25	3
STD + OG (STD + protective overgarments over the fatigues)	1.5	0.2	0.51	0.2	4

MICRO SAINT PROGRAMS FOR DEEP-BODY TEMPERATURE, HEART RATE, AND SWEAT LOSS

The Micro SAINT main computer program that models predictive equations for deep-body temperature, heart rate, and sweat loss of clothed soldiers performing physical work at various environmental extremes is listed in the appendix. The user is required to supply the input information in the scenario section in the program. The output consists of the predictive variables, and it is stored in the snapshot output files. We list here the input parameters for the model, the output, the output variables from the model, and an illustration of using the developed software.

INPUT PARAMETERS IN THE MODEL

The input parameters for the model are to be entered in the scenario section of the program as follows:

g = grade of terrian (%)

w = nude body weight (kg)

l = clothing and equipment weight (kg)

vm = walking velocity (m/s^{-1})

ad = body surface area (m^2)

ta = ambient temperature (°C) in a homogenous environment

pa = saturated water vapor pressure of air at T_{db} (mmHg)

tdb = dry bulb temperature (°C)

tsk = average skin temperature (°C)

psk = water vapor pressure at the skin (mmHg)

vair = air speed (m/s)

delt = duration of time interval in hours for execution of problem variables

treo = initial rectal temperature (°C)

phia = relative humidity (%)

adeff = effective surface area for evaporation (m^2)

trest = time duration in hours of the rest period

twork = time duration in hours of the work period

terrain = terrain number (Table 1) determining η as determined from the terrain table according to the type of terrain

trecovry = time duration in hours of the recovery period

closcond = a parameter (Table 2) determing the corresponding values for c_1, c_2, c_3, and c_4 according to the different types of clothing

OUTPUT VARIABLES FROM THE MODEL

The following output parameters are executed and stored in the Micro SAINT snapshot files at the end of tasks 2, 3, 4, 5 and 6:

total t = a time variable (h) with duration from beginning of rest cycle to end of recovery cycle.

t = a time variable with (h) duration from beginning of a corresponding cycle to its end

trecequib = final equilibrium temperature = T_{ref}

temprest = equilbrium temperature for rest cycle

hrrest = equilibrium heart rate for rest cycle

heartfr = final equilibrium heart rate for heat acclimated individuals = HR_f

swtlosrp = sweat-loss response (gm^{-2}h^{-1})

hrtrest = heart rate during rest cycle at time t

trecrest = rectal temperature during rest cycle at time t

rectemp = rectal temperature for rest-work recovery cycles at total t

hrtrate = heart rate for rest-work-recovery cycles at total t

trecwork = rectal temperature during work cycle at time t

hrtrwork = heart rate during work cycle at time t

trecov = rectal temperature during recovery cycle at time t

hrtrecov = heart rate during recovery at time t

The following is a listing of the snapshots for output variables executed at the end of tasks 2, 3, 4, 5, and 6; other parameters can be listed in the snapshots.

SNAPSHOTS OF EXECUTION

(1) Trigger:	End trigger	
(2) Task/Network:	2	equilib
(6) Snapshot file:	heateqlb	
Variables to store:		
(7) treceqlb		(8) swtlosrp
(9) heartfr		(10) hrrest
(11)		(12)

(1) Trigger:	End trigger	
(2) Task/Network:	3	rest temp-heart
(6) Snapshot file:	restth	
Variables to store:		
(7) t		(8) hrtrest
(9) trecrest		(10)
(11)		(12)

(1) Trigger:	End trigger	
(2) Task/Network:	4	work temp-heart
(6) Snapshot file:	workth	
Variables to store:		
(7) t		(8) hrtrwork
(9) trecwork		(10)
(11)		(12)
(1) Trigger:	End trigger	

(2) Task/Network:	5	recov temp-heart
(6) Snapshot file:	recovth	
Variables to store:		
(7) t		(8) hrtrecov
(9) trecov		(10)
(11)		(12)

(1) Trigger:	End trigger	
(2) Task/Network:	6	data collect
(6) Snapshot file:	sumheat	
Variables to store:		
(7) totalt		(8) hrtrate
(9) rectemp		(10)
(11)		(12)

ILLUSTRATION OF USING MICRO SAINT PROGRAMS AND ANALYSIS OF OUTPUT

The following are input parameters for an example run:

SIMULATION SCENARIO

(1) Event Time: 0.00

(2) Expression: terrain = 1;

closcond = 1;

g = 6;

w = 80;

l = 8;

vm = 1.3;

ad = 1.8;

treo = 37.2;

pa = 20;

phia = .62;

tdb = 35;

tsk = 36;

```
vair = 0.515;
psk = 44;
trest = 1;
twork = 1;
trecovry = 3;
ta = 35;
adeff = .8;
delt = .1;
```

The terrain and the closcond numbers are to be chosen from Tables 1 and 2, respectively, to present the environmental conditions stated in the tables. The main program assigns the terrain factor η and the climatic and closing conditions parameters automatically.

The corresponding output results from the snapshot taken at the end of task 2 are:

"clock"	"treceqlb"	"swtlosrp"	"Heartfr"	"hrrest"	"Trigger:"	"Jobs:"
0.000000	39.457581	789.714111	158.193024	83.903366	"End"	"2"

The corresponding output results from the snapshots taken at the end of tasks 3, 4, 5, and 6 are plotted, using Micro SAINT utilities, in Figs. 2, 3, 4, and 5, respectively.

Figure 2 represents the rectal temperature and heart rate in a rest cycle for 1 h duration. Figures 3 and 4 represent the temperature and heart rate during the work and recovery cycles, respectively. Figure 5 represents the temperature and heart rate for the three cycles; it indicates:

1) Rectal temperature exhibits a slow decrease during the rest cycle while heart rate exhibits moderate increase.
2) Rectal temperature and heart rate show large increases during the working cycle.
3) Heart rate reaches the resting equilibrium condition at a faster rate during the recovery cycle while the rectal temperature reaches the resting equilibrium condition at a slower rate.

For given environmental conditions, one can run the program for a prescribed duration for the rest and work cycles in order to determine the maximum time before the temperature and heart rate reach their maximum allowable conditions.

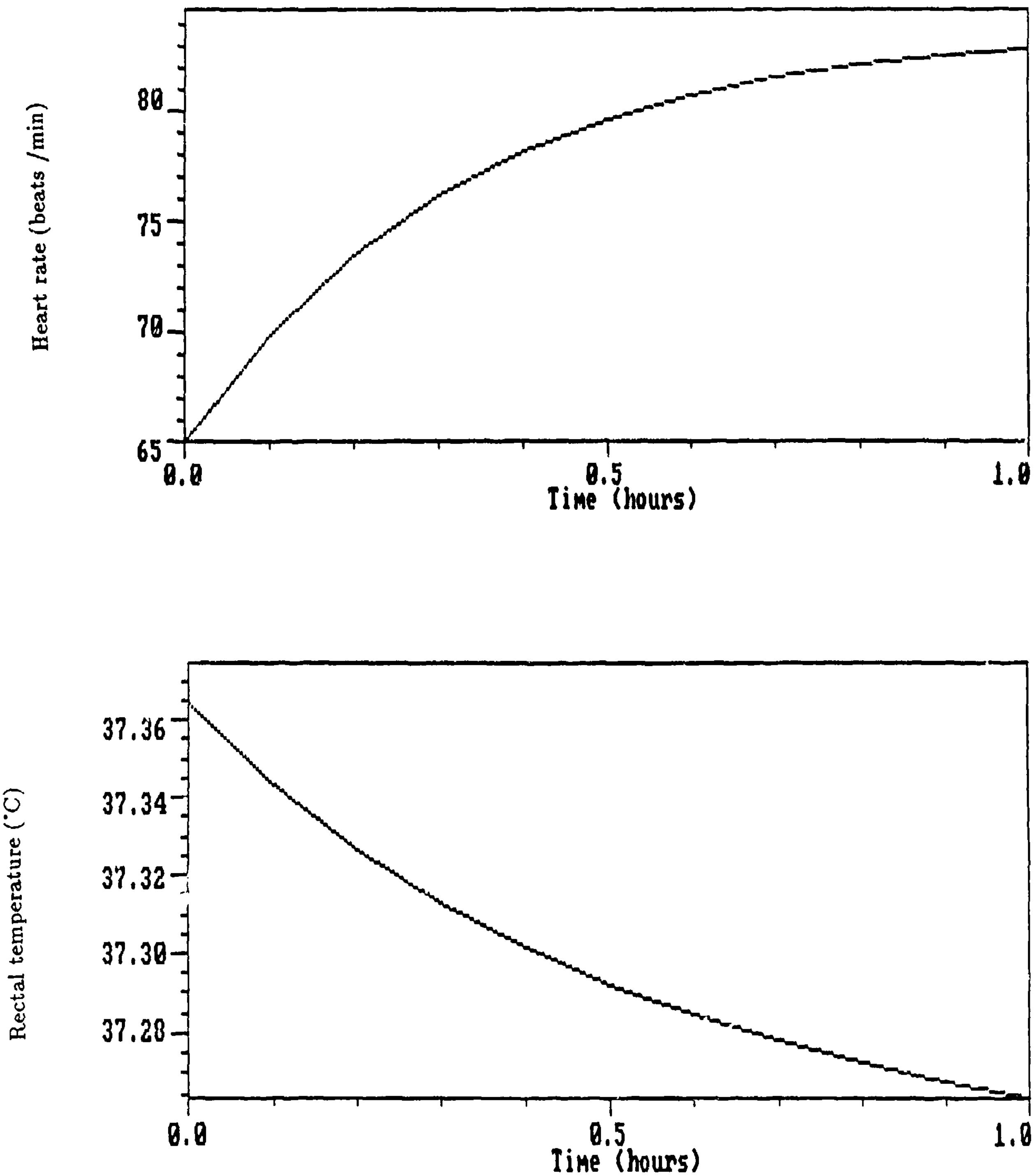


Figure 2. Heart rate and rectal temperature during rest cycle.

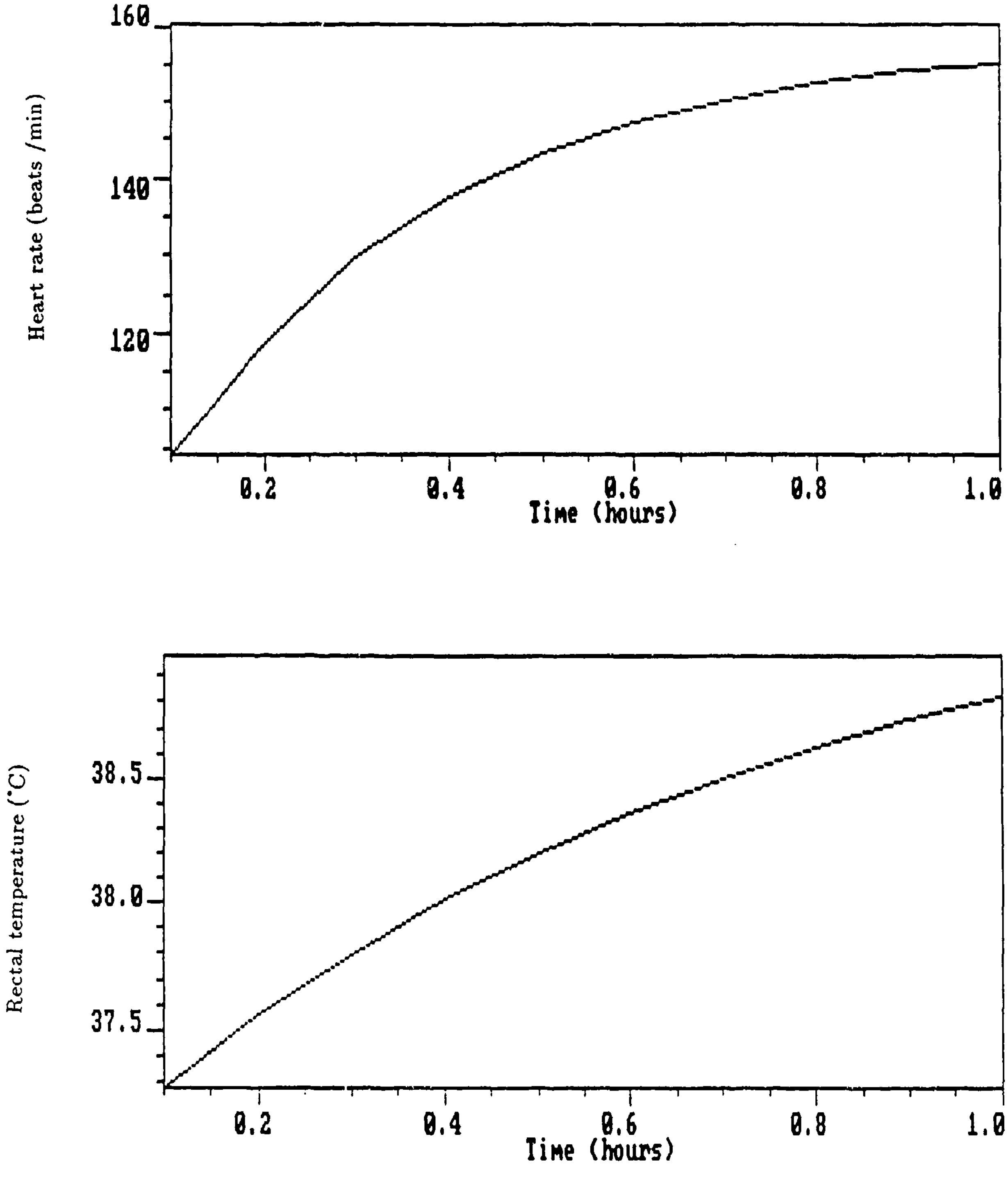


Figure 3. Heart rate and rectal temperature during work cycle.

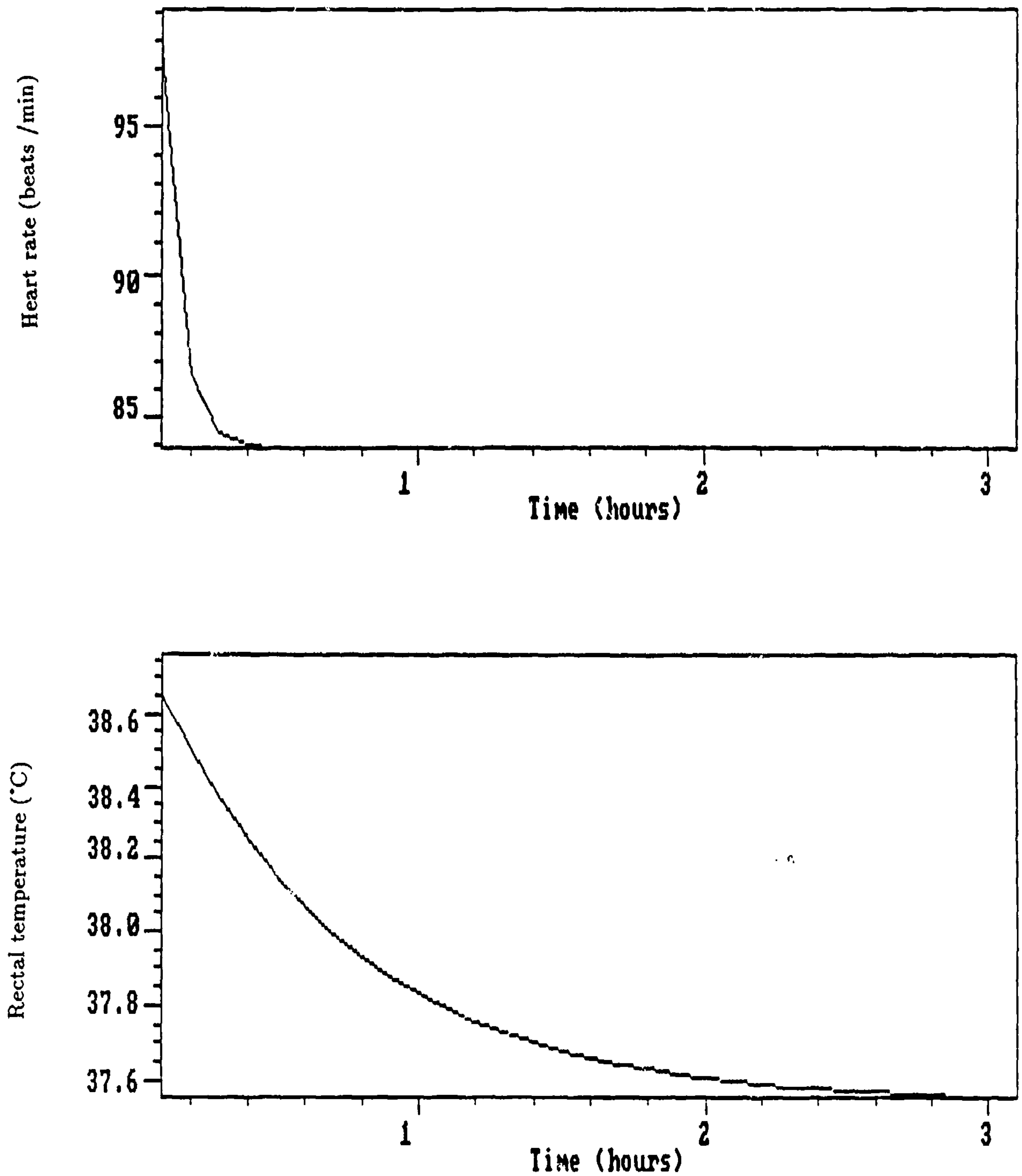
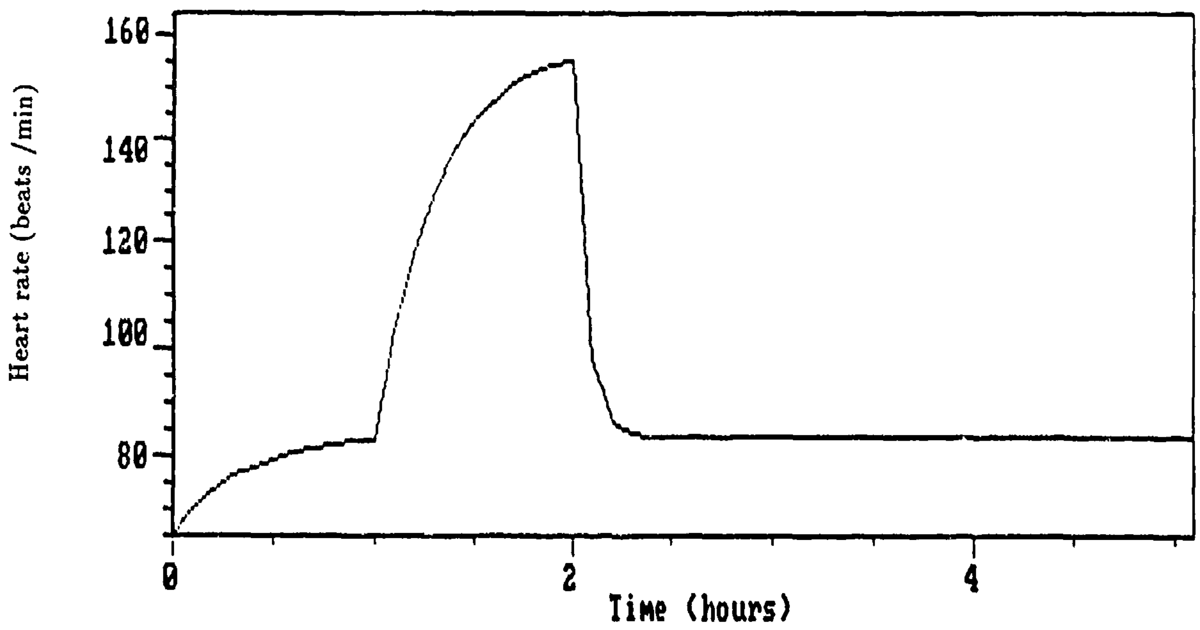


Figure 4. Heart rate and rectal temperature during recovery cycle.



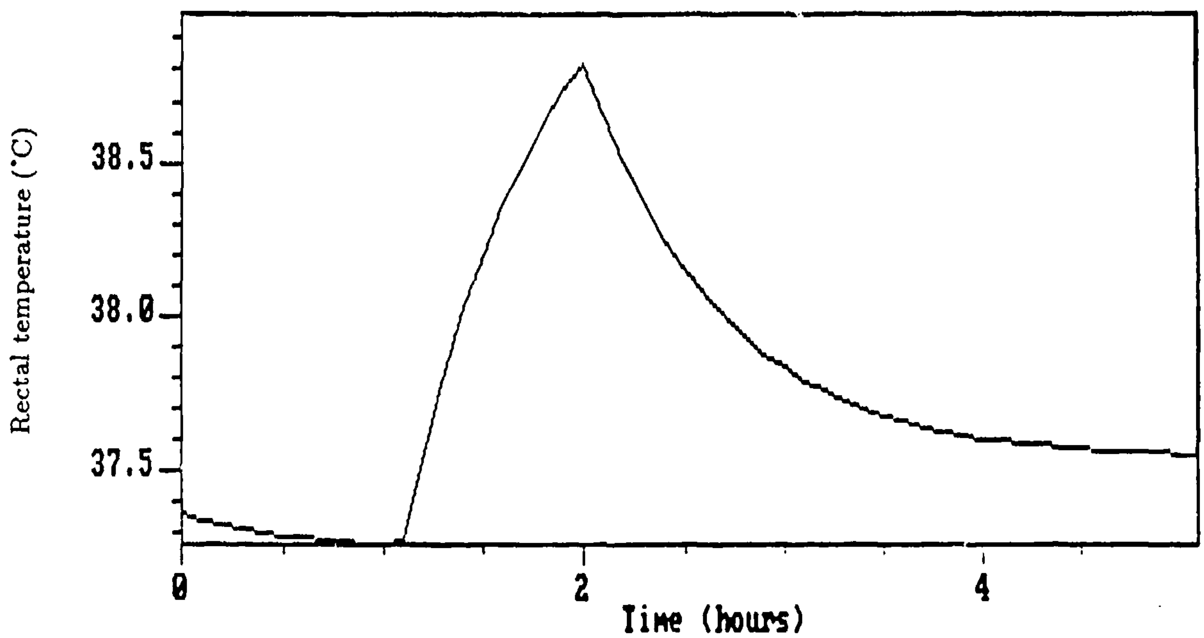


Figure 5. Heart rate and rectal temperature during rest, work, and recovery cycles.

4. CONCLUSION

We developed a Micro SAINT computer program for a series of predictive equations developed by the U.S. Army Research Institute of Environmental Medicine, (ARIEM), for deep-body temperature, heart rate, and sweat loss responses of clothed soldiers performing physical work at various environmental extremes. The user can employ this program by inserting input parameters in the scenario section of the Micro SAINT program.

This computational module could be used to help reduce casualties associated with environmental heat extremes and to predict appropriate work-rest cycles and water requirements equivalent to sweat loss.

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APPENDIX

MICRO SAINT NETWORK AND PROGRAM PRINTOUTS

TASK NETWORK

```
Network Number:  0
(1)  Name:  heat                                    (2)  Type:  Network
(3)  Upper Network:
(4)  Release Condition:  1;
(5)  First Sub-job:  start  initial
(6)  Sub-jobs (each can be task or network):
Number:        Name:                 Type:
start          initial               Task
2              equilib               Task
3              rest temp-heart       Task
4              work temp-heart       Task
5              recov temp-heart      Task
6              data collect.         Task
7               end                   Task

Task Number:  start
(1)  Name:  initial                                 (2)  Type:  Task
(3)  Upper Network:  0  heat
(4)  Release Condition:  1;
(5)  Time Distribution Type:  Normal
(6)  Mean Time:  0;
(7)  Standard Deviation:  0;
(8)  Task's Beginning Effect:
(9)  Task's Ending Effect:  exp=2.71;t=0;totalt=0;t3=0;tcount=0;
(10) Decision Type:  Single choice
     Following Task/Network:        Probability Of Taking
      Number:          Name:          This Path:
(11)  2                equili   (12)  1;
(13)                            (14)
(15)                            (16)
(17)                            (18)
(19)                            (20)
(21)                            (22)
(23)                            (24)

Task Number:  2
(1)  Name:  equilib                                 (2)  Type:  Task
(3)  Upper Network:  0  heat
(4)  Release Condition:  1;
(5)  Time Distribution Type:  Normal
(6)  Mean Time:  0;
(7)  Standard Deviation:  0;
(8)  Task's Beginning Effect:
(9)  Task's Ending Effect:  if terrain ==  1 then eta=1.0;
if terrain ==  2 then eta=1.1;
if terrain ==  3 then eta=1.2;
if terrain ==  4 then eta=1.3;
if terrain ==  5 then eta=1.5;
if terrain ==  6 then eta=1.8;
if terrain ==  7  then eta=2.1;
if terrain ==  8 then eta=1.38;
m=1.5*w+20*(w+l)*(l/w)^2+eta*(w+l)*(1.5*vm*vm+0.35*vm*g);
mrest=1.5*w+20*(w+l)*(l/w)^2;wexrest=0;
wex=0.098*g*(w+l)*vm;
veff=vair+.004*(m-105);
veffrest=vair+.004*(mrest-105);
if closcond ==  1 then clo=0.57*veff^((-1)*0.3);
if closcond==1 then clorest=0.57*veffrest^((-1)*.3);
if closcond ==  1 then imperclo=1.2*veff^.3;
if closcond==1 then imclorst=1.2*veffrest^.3;
if closcond ==  2 then clo=.74*veff^((-1)*0.28);
if closcond==2 then clorest=.74*veffrest^((-1)*.28);
if closcond ==  2 then imperclo=.94*veff^.28;
if closcond==2 then imclorst=.94*veffrest^.28;
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if closcond ==  3 then clo=0.99*veff^((-1)*.25);
if closcond==3 then clorest=.99*veff^((-1)*.25);
if closcond ==  3 then imperclo=0.75*veff^.25;
if closcond==3 then imclorst=.75*veffrest^.25;
if closcond ==  4 then clo=1.5*veff^((-1)*.2);
if closcond==4 then clorest=1.5*veffrest^.2;
if closcond ==  4 then imperclo=.51*veff^.2;
if closcond==4 then imclorst=.51*veffrest^.2;
itrest=clorest;it=clo;
im=imperclo*clo;imrest=imclorst*clorest;
hrpc=6.45*ad*(tdb-tsk)/it;hrpcrest=6.45*ad*(tdb-tsk)/itrest;
dryhtexg=0.0011*hrpc;
ereq=(m-wex)+hrpc;
ereqrest=(mrest-wexrest);
emax=14.21*(im/it)*adeff*(psk-phia*pa);
emaxrest=14.21*(imrest/itrest)*adeff*(psk-phia*pa);
evaphtex=.8*exp^(0.0047*(ereq-emax));
evaprest=.8*exp^(.0047*(ereqrest-emaxrest));
treceqlb=36.75+0.004*(m-wex)+0.0011*hrpc+evaphtex;
temprest=36.75+0.004*(mrest-wexrest)+.0011*hrpcrest+evaprest;
swtlosrp=27.9*ereq*emax^((-1)*0.455);
ihr=100*(treceqlb-36.75)+.4*wex;
if ihr <=225 & ihr >=  25 then heartfr=65+0.35*(ihr-25);
if ihr >  225 then heartfr=135+45*(1-exp^((-.01)*(ihr-225)));
if ihr < 25 then heartfr=65;
ihrrest=100*(temprest-36.75)+.4*wexrest;
if ihrrest <=  225 & ihrrest>=  25 then hrrest=65+0.35*
(ihrrest-25);
if ihrrest >  225 then hrrest=135+45*(1-exp^((-.01)*
(ihrrest-225)));
if ihrrest < 25 then hrrest=65;
(10) Decision Type:  Single choice
     Following Task/Network:      Probability Of Taking
      Number:       Name:          This Path:
(11)  3             rest t   (12)  1;
(13)                         (14)
(15)                         (16)
(17)                         (18)
(19)                         (20)
(21)                         (22)
(23)                         (24)

Task Number:  3
(1)  Name:  rest temp-heart                        (2)  Type:  Task
(3)  Upper Network:  0  heat
(4)  Release Condition:  1;
(5)  Time Distribution Type:  Normal
(6)  Mean Time:  0;
(7)  Standard Deviation:  0;
(8)  Task's Beginning Effect:
(9)  Task's Ending Effect:
trecrest=treo+(temprest-treo)*0.1*exp^(0.4^(t-0.5));
hrtrest=65+(hrrest-65)*(1-exp^((-1)*3*t));
if t >=  trest then treow=trecrest;  if t >=  trest then tcount=0;
rectemp=trecrest;hrtrate=hrtrest;
(10) Decision Type:  Single choice
     Following Task/Network:      Probability Of Taking
      Number:       Name:          This Path:
(11)  6             data c   (12)  1;
(13)                         (14)
(15)                         (16)
(17)                         (18)
(19)                         (20)
(21)                         (22)
(23)                         (24)
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Task Number:  4
(1)  Name:  work temp-heart                          (2)  Type:  Task
(3)  Upper Network:  0  heat
(4)  Release Condition:  1;
(5)  Time Distribution Type:  Normal
(6)  Mean Time:  0;
(7)  Standard Deviation:  0;
(8)  Task's Beginning Effect:
(9)  Task's Ending Effect:
  tref=trecequib;hrf=heartfr;t2=(t-(58/m));
if t2 >  0 then trecwork=treow+(tref-treow)*(1-exp^((-1)*2*exp^((-1)*
.17*(tref-treow))*(t-(58/m))));
hrtrwork=65+(hrf-65)*(1-.8*exp^((-1)*(6-0.03*(hrf-65)
)*t));
if t2 <=  0 then trecwork=  treo+(temprest-treo)*.1*exp^(.4^(t3-.5));
if t >=  twork then tcount=0 ;if tcount==0 then t1=twork+delt;
if t >=  twork then trew=trecwork;
rectemp=trecwork;hrtrate=hrtrwork;
(10) Decision Type:  Single choice
     Following Task/Network:      Probability Of Taking
      Number:        Name:          This Path:
(11)  6              data c   (12)  1;
(13)                          (14)
(15)                          (16)
(17)                          (18)
(19)                          (20)
(21)                          (22)
(23)                          (24)

Task Number:  5
(1)  Name:  recov temp-heart                         (2)  Type:  Task
(3)  Upper Network:  0  heat
(4)  Release Condition:  1;
(5)  Time Distribution Type:  Normal
(6)  Mean Time:  0;
(7)  Standard Deviation:  0;
(8)  Task's Beginning Effect:
(9)  Task's Ending Effect:  hrr=hrrest;
k=2-.01*(hrtrwork-hrr);
cpeff=.27*imclorst*(psk-phia*pa)+(.174/clorest)*(36-ta)-1.57;
b=2+12*(1-exp^((-1)*.3*cpeff));
tdrec=.25*exp^((-1)*.5*cpeff);
alpha=1.5*(1-exp^((-1)*1.5*cpeff));
trer=temprest;
if t < tdrec then trecov=treo+(tref-treo)*(1-exp^((-1)*2*exp^
((-1)*.17*(tref-treow))*(t1-(58/m))));
t1=t1+delt;
if t < tdrec then trecov =trecwork+.5*(trecov-trecwork);
if t < tdrec | trecov >=trew  then trew=trecov;
if t >=tdrec then trecov=trew-(trew-trer)*(1-exp^((-1)*alpha*
(t-tdrec)));
hrtrecov=hrtrwork-(hrtrwork-hrr)*(1-exp^((-1)*k*b*t));
rectemp=trecov;hrtrate=hrtrecov;
(10) Decision Type:  Single choice
     Following Task/Network:      Probability Of Taking
      Number:        Name:          This Path:
(11)  6              data c   (12)  1;
(13)                          (14)
(15)                          (16)
(17)                          (18)
(19)                          (20)
(21)                          (22)
(23)                          (24)

Task Number:  6
(1)  Name:  data collect.                            (2)  Type:  Task
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(3)  Upper Network:  0  heat
(4)  Release Condition:  1;
(5)  Time Distribution Type:  Normal
(6)  Mean Time:  0;
(7)  Standard Deviation:  0;
(8)  Task's Beginning Effect:
(9)  Task's Ending Effect:  tcount=tcount+delt;t=tcount;
if t3 <=  trest then flag=1;
if t3 >  trest & t3 <=  trest+twork then flag=2;
if t3 >  trest+twork & t3 <=  trest+twork+trecovry then flag=3;
if t3 >  trest+twork+trecovry then flag=4;
t3=t3+delt;totalt=t3-delt;
(10) Decision Type:  Tactical
     Following Task/Network:       Tactical Expression:
      Number:        Name:
(11)  3              rest t  (12)  flag==1;
(13)  4              work t  (14)  flag==2;
(15)  5              recov   (16)  flag==3;
(17)  7               end     (18)  flag==4;
(19)                         (20)
(21)                         (22)
(23)                         (24)

Task Number:  7
(1)  Name:  end                                      (2)  Type:  Task
(3)  Upper Network:  0  heat
(4)  Release Condition:  1;
(5)  Time Distribution Type:  Normal
(6)  Mean Time:  0;
(7)  Standard Deviation:  0;
(8)  Task's Beginning Effect:
(9)  Task's Ending Effect:
(10) Decision Type:  Last task
     Following Task/Network:       Probability Of Taking
      Number:        Name:          This Path:
(11)                         (12)
(13)                         (14)
(15)                         (16)
(17)                         (18)
(19)                         (20)
(21)                         (22)
(23)                         (24)
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Other Related NAMRL Publications

Shamma, S., Molina, E.A., and Stanny, R.R. Micro SAINT Programs for Numerical Methods of Integration and Differential Equations, NAMRL Monograph 39, Naval Aerospace Medical Research Laboratory, Pensacola, FL, September 1989. (AD A218 097)